# Accelerated Life Testing and Data Analysis for Lithium-Ion Cells

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## ABSTRACT

Sandia is studying the performance of 18650-size lithium-ion cells fabricated to represent the high-power battery chemistry being developed for use in hybrid electric vehicles (HEVs). One of our objectives in this work for the Advanced Technology Development (ATD) Program is to develop procedures to rapidly determine performance degradation rates while these cells undergo life tests. This information will be applied to enable efficient predictions of battery life to be made for the HEV use environment.

The original high-power cell design studied uses a mixed metal (Ni/Co) oxide cathode material, a graphitic carbon anode, and an ethylene carbonate (EC)/diethyl carbonate (DEC) electrolyte containing $LiPF_6$ salt. The behavior of a similar second-generation design that uses an EC/ethyl methyl carbonate (EMC) electrolyte solvent is the focus of the current study.

Long-life lithium-ion cells will require accelerated test conditions in order to observe degradation within a reasonable time period. In this study, temperature, state-of-charge, and cycle profile are investigated as multiple sources of acceleration. Complex ac impedance studies, including measurements at subambient temperature, are being conducted to provide a sensitive detection method for subtle changes in the cell. The lithium-ion cells are stored at temperatures ranging from 25 to 55°C and at various states-of-charge (SOCs) between 60 and 100%. Cells will be periodically evaluated for capacity, pulse power capability, and impedance until significant amounts of degradation have occurred. In most cases, the cells are stored open circuit, but a small screening study will also be carried out to determine the effect of cycling as an additional acceleration factor.

After high-temperature aging, the original cell design typically showed a decreased power capability in standard Partnership for a New Generation of Vehicles (PNGV) tests and capacity was also markedly reduced [1]. Previous complex ac impedance studies revealed an increasing interfacial impedance loop and a fairly constant ohmic component. Three-electrode studies have shown that the dominant contribution to the increasing interfacial impedance arises from the positive electrode [2].

Changes observed in the impedance measurements have been correlated to the performance data. A singular value decomposition of the complex impedance data was performed to identify the principal components and these were correlated to various measures of the pulse power and capacity fade. Figure 1 shows the relation between the pulse power limit and principal impedance component. Based on analysis of the early impedance results, the main contributor to the impedance increase remains the interfacial impedance. This component was responsible for more than 90% of the characteristic shape of the impedance curve.

Using these correlations, the statistical character of the measurements is being obtained and a life prediction, including confidence bands, will be made. The long-range goal is to construct an artificial neural network model to interpolate more accurately between the measured points so that performance and life can be predicted under typical use conditions.

Our conclusion at this point is that the degradation of cell power capability can be accelerated by a combination of temperature, high SOC and cycling. Extrapolation of the degradation rates to typical use conditions is being confirmed by storage at lower temperature and SOC to provide some validation of the life predictions.

## ACKNOWLEDGMENT

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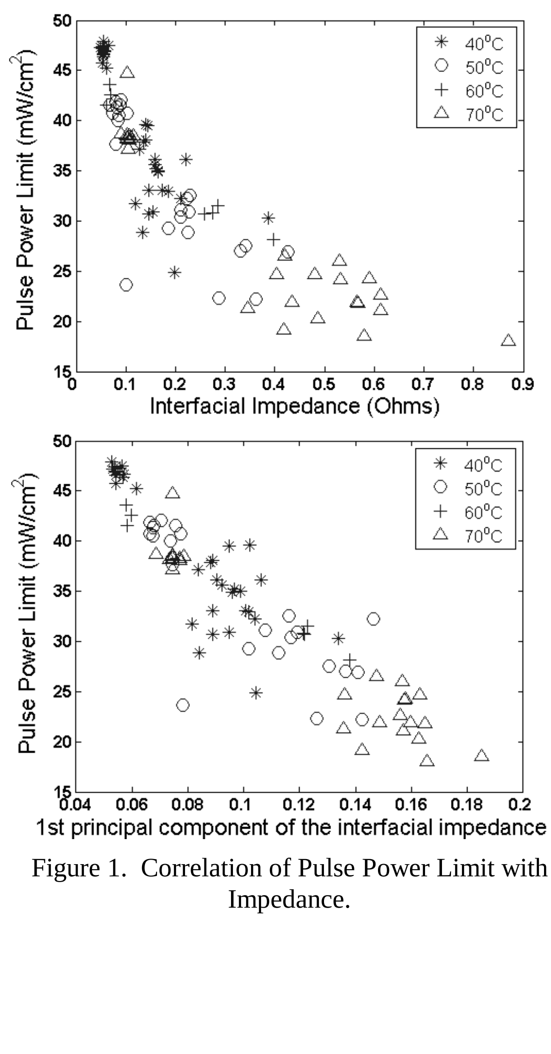


Figure 1. Correlation of Pulse Power Limit with Impedance.